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January 30, 2003

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Subject: **Draft Yerington Pit Lake Work Plan**
Yerington Mine Site, Lyon County, Nevada

Dear Art:

Atlantic Richfield Company is pleased to submit the attached Draft Yerington Pit Lake Work Plan, pursuant to the Yerington Mine Site Closure Scope of Work.

If you have any questions regarding the attached document, please contact me at 1-406-563-5211 ext. 430.

Sincerely,

Dave McCarthy
Project Manager

cc: Robin Bullock, Atlantic Richfield Company
Bonnie Arthur, SFD-8-1, USEPA Region 9
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Elwood Emm, Yerington Paiute Tribe
John Krause, Bureau of Indian Affairs
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Vicki Roberts/Johanna Emm, Yerington Paiute Tribe
Paul Thomsen, Office of Senator Harry Reid
Phyllis Hunewill, Lyon County Board of County Commissioners
Joe Sawyer, SRK Consulting
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DRAFT

YERINGTON PIT LAKE

WORK PLAN

JANUARY 30, 2003

PREPARED FOR:

Atlantic Richfield Company
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SECTION 1.0
INTRODUCTION

Atlantic Richfield Company has prepared this Draft Yerington Pit Lake Work Plan (Work Plan) to conduct field investigations that will support an evaluation of ecological and human health risk associated with the Pit Lake, and an evaluation of potential impacts to groundwater resulting from the refilling of the Yerington Pit with groundwater, surface water run-off and direct precipitation. Investigations proposed in this Work Plan will be conducted pursuant to the Closure Scope of Work (SOW; Brown and Caldwell, 2002a), and "will aid in the development of closure and management alternatives for the pit lake". Specifically, data will be collected to:

- Evaluate the hydraulic relationship (i.e., water levels and gradient) between the bedrock groundwater flow system that surrounds the Yerington Pit and the water in the pit;
- Develop a pit lake water balance and estimate "steady-state" hydrologic conditions to determine the long term flow direction between the bedrock flow system and the pit;
- Confirm the hydrochemical stability of the pit lake to provide the basis to assess potential impacts to groundwater, if the pit has the potential to become a flow-through system, and potential human health or ecological risk.

The remainder of Section 1.0 of this Work Plan describes past mining operations and current site conditions that may affect the pit lake water balance and pit water quality, previous investigations and related studies, and a description of Data Quality Objectives for the proposed field investigations. Section 2.0 presents a conceptual pit lake model that includes hydrogeologic, geochemical and limnological components. Section 3.0 presents the specific field activities proposed to achieve the Data Quality Objectives and refine the conceptual pit lake model. Section 3.0 also presents quality control procedures, based on the Draft Quality Assurance Project Plan (QAPP), and a task-specific Job Safety Analysis in the context of the existing comprehensive Site Health and Safety Plan. Section 4.0 lists references cited in this Work Plan.

1.1 Location

The Yerington Mine Site is located west and northwest of the town of Yerington in Lyon County, Nevada (Figure 1). The Walker River flows northerly and northeasterly past the mine site, between the site and the town of Yerington. The river is within a quarter-mile of the southern portion of the site, and the distance between the site and the river increases to the north. Highway 95A is also located between the mine site and the town of Yerington (Figure 1). The Paiute Tribe Indian Reservation is located approximately 2.5 miles north of the site.

The Yerington Mine Site is located in Mason Valley and the Mason Valley hydrographic basin (no. 108) within the Walker River watershed. Agriculture has been the principal economic activity in Mason Valley (principally hay and grain farming, with some beef and dairy cattle ranching). Local onion farming is also present in the area. Surface water diversions from the Walker River and groundwater pumping provide the irrigation water for these agricultural activities.

1.2 Past Mining Operations and Current Conditions

Mining and beneficiation operations for oxide and sulfide copper ores from an open-pit in the southern portion of the mine site were conducted between 1953 and 1978 by Atlantic Richfield's predecessor, the Anaconda Mining Company. Waste rock piles were constructed to the south and to the north of the open pit. Arimetco, Inc. acquired the property in 1989, and initiated leaching operations at five lined leach pads located around the site, including the re-handling and leaching of previously deposited tailings and waste rock north of the pit. Mine units at the site are shown in Figure 2.

Dewatering/production wells were installed in the bedrock around the perimeter of, and within, the Yerington Pit to lower the potentiometric surface in the bedrock groundwater flow system. Some of the remaining perimeter wells are shown in Figure 3, along with other monitor wells. Groundwater pumped from these wells lowered the potentiometric surface in the bedrock and allowed for dry, safe mining conditions in the open pit. The pumped water was used to supply the plant and townsite (Anaconda Mining Company, 1968). The Anaconda Mining Company (1968) reported that the original water table occurred at an elevation of 4,370 to 4,375 feet above mean sea level (amsl). This range of elevations is approximately 175 to 25 feet lower than the range of pit rim elevations (4,550 feet amsl on the west rim; 4,400 feet amsl on the east rim) based on 2001 aerial photography and topographic mapping. Seegmiller (1978) indicated a range of pre-mining groundwater elevations from 4,350 to 4,360 feet amsl. Per the Anaconda Mining Company 1968 report, the average pumping rate for the wells at that time was about 3,400 acre-feet per year (AFY), or about 2,100 gallons per minute (gpm) on a continuous basis.

Since 1978, the Yerington Pit Lake has refilled with groundwater, direct precipitation, surface water run-off and seepage from highwall springs developed in the alluvium or the alluvium-bedrock contact. The stage-volume relationship for the pit is presented in Table 1. The volume of water shown for each stage (elevation) is cumulative for that specific elevation. Table 2 presents available pit lake surface elevation measurements from 1990 to 2002, available from Ron Hershey (DRI; written comm., 2002), mine site files and measurements by Mr. Joe Sawyer (SRK, written comm., 2002). Water levels in the Yerington Pit have risen from 4,106 feet amsl in December 1990 to about 4,191 feet amsl in October 2002, a total of about 85 feet in approximately 12 years (an average increase of about 7 feet per year). Above-average inflows to the pit were experienced during 1997 when floodwaters from the Walker River were diverted into the pit to mitigate property damage in the area (Ron Hershey (DRI; pers. comm., 2002).

Measured pit lake elevations since 1990 are graphically presented in Figure 4A. These elevations and interpreted pre-1990 elevations since pit refilling began in 1978 (presumed to be mid-1978), are shown in Figure 4B. The shape of the recovery curve is commonly seen in pit lakes developed in hard rock mining environments (e.g., Moreno and Sinton, 2002).

1.3 Physical Setting

This section describes the physical setting of the Yerington Pit Lake. Information presented in this section includes climate, geology, hydrogeology, surface water hydrology around the pit, a description of recharge and discharge components in the context of a preliminary pit water balance, and the limnologic character of the pit lake. Previous and ongoing studies that specifically address the pit lake include the Nevada Division of Environmental Protection (NDEP), PTI Environmental Services (Atkins, et. al., 1997), site investigations conducted by the

University of Utah for the NDEP (Jewell, 2002), and the Ph.D. dissertation of Mr. Ron Hershey of the Desert Research Institute.

Climatic Setting

Huxel (1969) summarized the climate of the Mason Valley area as arid to semi-arid. Precipitation generally occurs as winter snows in the mountain blocks, and summer thundershowers both on the mountains and valley floor. Precipitation averages 20 inches in the mountains and 5 inches on the valley floor. Huxel (1969) cited an evaporation rate of approximately 4 feet, and described prevailing winds and storm trajectories that cross the valley as being generally from the west. The estimated pan evaporation rate for the site is about 37 inches per year based on data from Fallon, which has a similar climate (Piedmont Engineering, 2001). The precipitation and evaporation data indicate a water balance strongly dominated by evaporation, resulting in a net loss condition for the valley floor and lower alluvial fan areas where the Yerington Pit is located.

The University of Utah established a portable meteorological station near the water surface on the southern access road to the lake from May 1998 to May 1999 (Jewell, 2002; written comm.). The station sampled wind direction and speed and air temperature every hour. The data were stored internally and downloaded during visits to the lake (about every 6-7 weeks). A continuous meteorological record was collected for the periods from May 2 to September 18, 1998 and from December 12, 1998 to May 12, 1999. The gap in the record toward the end of 1998 was the result of a computer malfunction (Jewell, 2002).

Jewell (2002) noted that the Yerington Mine Site is located in the rain shadow of the Sierra Nevada. The site receives extremely low annual rainfall (5.3 inches or 13.5 cm per year). The precipitation data was obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu). Jewell also reported evaporation rates (using combined Fallon and Yerington data sets) of 0.6-0.7 meters per year, and compared these to published values of pan evaporation rates of 1.2-1.5 m/yr for this area of Nevada (e.g., Dingman, 1994, Figure 7-6).

These data indicate that the Pit Lake is located in a strongly net evaporative area. Evaporation is directly proportional to wind velocity as well as surface air temperature, net longwave and shortwave radiation (largely a function of cloud cover), relative humidity and atmospheric pressure (Jewell, 2002). Atlantic Richfield is currently collecting site-specific meteorological and evaporation data in the area of the pumpback wells.

Geologic Setting

The Yerington Mine is located at the base of the Singatse Range on the west side of Mason Valley, a structural basin surrounded by uplifted mountain ranges common to the Basin-and-Range physiographic province. Copper mineralization was hosted in a Jurassic-age quartz-monzonite porphyry (part of the composite Yerington batholith) that intruded a thick sequence of Triassic-age metamorphic rocks, composed of various meta-volcanic and meta-sedimentary units (Wilson, 1963). The geometry of the porphyry was noted to be elongated in a N 60^{o}W direction, approximately 6,000 in length, and 2,200 feet in width at its eastern exposure and 1,000 feet in width at its western margin (Wilson, 1963). The porphyry consisted of a complex series of igneous intrusions with grano-diorite and quartz-monzonite on the north, grano-diorite and a variety of other igneous lithologic types on the south, and tonalite on the west (Wilson, 1963). The porphyry was cut by a number of Tertiary-age, post-mineral rhyolite and andesite dikes, a common expression of bi-modal volcanism in the western Nevada. The metamorphic country rock, mineralized porphyry and later dikes and associated volcanic rocks represent the major lithologic units exposed in the Singatse Range in the area of the Yerington Mine (Wilson, 1963).

The distribution of copper ore generally conformed to the geometry of the porphyry, with a maximum thickness of 800 feet in cross-section. High-grade ore in the central portion of the deposit was composed of chalcopyrite with pyrite as the other important sulfide mineral. Minor bornite, covellite and chalcocite also occurred as secondary sulfides. Sulfides were noted to occur as minute, discrete grains in the groundmass and phenocrysts (larger crystals) of the porphyry.

The oxidation front in the deposit was generally distinct and somewhat undulating. Its maximum vertical extent was along the eastern portion of the deposit where essentially all sulfides had been oxidized (Wilson, 1963). The major oxidation product was chrysocolla, with minor occurrences of other copper oxides. Locally, a transition zone between the oxide and sulfide minerals was noted (Wilson, 1963).

Copper mineralization did not appear to have been cut-off or lost due to post-mineral basin-and-range style faulting (Wilson, 1963). The host rocks were cut by a series of shear zones that were oriented parallel to the long axis of the porphyry (N 60^{o}W), or that trended in a north-south direction. After emplacement of the porphyry and associated copper mineralization, the deposit was subjected to tilting approximately 55^o as a result of complex Basin-and-Range style extensional (i.e., listric) faulting. If re-constructed prior to mining, the Yerington copper deposit would have appeared as a steep, southeast-plunging ore body, suggesting an original vertical extent of copper mineralization of over 4,000 feet (Wilson, 1963). Proffett (1977) noted that at least 100 percent of structural extension in an east-west direction due to Basin-and-Range faulting occurred in the area of the Yerington Mine Site, with the greatest rate of extension between 11 and 17 million years before present. Dilles and Gans (1995) noted at least 150 percent of structural extension younger than 15 million years before present.

Proffett and Dilles (1984) published a geologic map of the Yerington Mining District, and a portion of this map that presents the general geology of the open pit is reproduced as Figure 4. The geologic map shows three major igneous rock types of the Yerington batholith, and a small sliver of Tertiary volcanic and volcaniclastic rocks in the northwest corner of the pit. The internal structure of the igneous rocks exposed within the pit appears to be generally oriented along the long axis (northwest orientation) of the pit.

Geologic cross-sections (A-A' and C-C') through the Yerington Pit from Proffett and Dilles (1984) are reproduced as Figures 5 and 6, respectively (an explanation for the geologic features shown in these figures is available in the referenced report). The pit area is shown in relation to the major structural features at the site on section A-A'. These faults generally strike to the north and dip to the east. The Range Front Fault, shown on the eastern side of section A-A', shows the down-dropped structural basin with the Walker River, against the structural block that contains the Yerington Pit. The Sales Fault bounds the western margin of the structural block that contains the Yerington Pit and exhibits a large degree of rotation, as evidenced by the stratigraphy of the Tertiary volcanic rocks against the fault. Low-angle faults (Singatse and May Queen Faults) appear to form a structural bottom to the block that contains the pit, also depicted on section C-C'.

A map of structural elements within the pit was prepared by Seegmiller Associates (1979) for Anaconda Mining Company as part of a rock mechanics and slope stability study to determine the physical stability of the Yerington Pit walls after groundwater has refilled the pit. This map is reproduced in this Work Plan as Figure 7. Seegmiller identified one major structural feature with a strike length of approximately 3,000 feet, the Sericite Fault, in the pit. The strike of the Sericite Fault varies from east to northeast with dips approximately 50^{o} to 70^{o} to the north and northwest, parallel or sub-parallel to a number of minor faults up to 1,200 feet in length exposed in the eastern portion of the pit. The western portion of the pit also exhibits minor faults that generally strike east to northeast with moderate to steep dips (45^{o} to 90^{o}).

Seegmiller (1978) observed that, at any given location within the pit, three major joint sets occur. The major joint sets may be accompanied by one or two moderate and up to three minor joint sets in many places. Given the numerous joint sets, the igneous rocks within the pit that hosted the copper ores were broken into blocks with an average size of 4 to 6 inches.

Pit Hydrogeology

Dewatering of the Yerington Pit to support mining operations beneath the pre-mining potentiometric surface of approximately 4,350 to 4,375 feet amsl (Anaconda Mining Company, 1968 and Seegmiller, 1979) required the use of dewatering/production wells. A relatively small number of these wells that remain are shown in Figure 3. It is presumed that some of the dewatering wells within the pit or around the pit perimeter were constructed to depths below the ultimate pit bottom (3,800 feet amsl) in order to maintain a "dry" pit. The range of reported pre-mining groundwater elevations is not uncommon in fractured bedrock flow systems where clay-filled faults can compartmentalize groundwater flow into discrete hydrogeologic blocks. Seegmiller (1979) noted that perched groundwater tables were common in most of the pit slopes. Although little information is available for the wells that were used to dewater the pit, their combined average production rate of approximately 2,100 gpm was adequate to allow mining to advance to the 3,800-foot elevation.

As described above, the fractured nature of the igneous host rocks in the pit may locally transmit groundwater as an effective porous media. However, discrete structural elements in the Yerington Pit will likely influence groundwater inflows. Typically, groundwater flow is impeded across clay-bearing or clay-rich faults and flow is enhanced along the strike of structures that exhibit brittle fracture (with open spaces). Although no data is available for inflow rates from the bedrock flow system, the bedrock contribution from pit refilling data can be back-calculated using the pit lake water balance analysis proposed in this Work Plan.

Exposure of the alluvium within the highwalls of the Yerington Pit caused some portion of groundwater flow in the alluvial fan to flow into the pit as a series of springs, principally along the alluvium-bedrock contact (as seen at the present time along the western margin of the pit). Seegmiller (1979) noted that groundwater along the bedrock-alluvium contact at the west end of the pit was normally encountered during mining. Similarly, inflows along the eastern margin of the Yerington Pit likely resulted from the highwall exposure of the alluvium in this area. It is likely that these highwall "springs" were managed during mining operations in the Yerington Pit.

At present, the Yerington Pit intercepts groundwater flow from the bedrock and alluvial flow systems at the southern end of the mine site. Groundwater inflows at the west end of the pit from the alluvial aquifer along the bedrock-alluvium contact have been measured at rates up to approximately 50 gpm (Hershey, 2002; pers. comm.). However, it is not known how much of this inflow results from water losses associated with businesses and residential units in Weed Heights, as suggested by observed nitrate concentrations in this highwall spring. Hershey (2002; pers. comm.) measured seepage from the Walker River through the alluvium at the east margin of the pit at rates of approximately 100 to 120 gpm.

Figure 8 shows the bedrock groundwater elevation measured in June 2002 in well WW-59, located northwest of the Yerington Pit (measured as part of the site-wide groundwater monitoring event by AHA). This is the only currently accessible bedrock well along the pit perimeter. The groundwater elevation measured in WW-59 (4,309 feet amsl) can be compared to the most recent pit lake elevation measurement (4,190 feet amsl) obtained by Joe Sawyer. Well WW-36, also constructed in the bedrock, is a pumping well that supplies water to Weed Heights for municipal and industrial use (Joe Sawyer, 2002, pers. comm.). However, because it is a pumping well, a static water elevation cannot be measured in WW-36 for comparison to WW-59 or the pit lake surface. Assuming "isotropic" conditions in the fractured bedrock aquifer around the pit, preliminary groundwater elevation contours are also presented in Figure 8.

Water Quality Data

Groundwater and surface water quality data associated with the Yerington Pit are available from the following locations:

- Three groundwater production wells completed in the bedrock aquifer (WW-36, WW-59 and W2B);
- Highwall springs that flow into the pit lake (east and west pit margins); and
- Pit water from various depths (surface to 100 meters below the surface of the pit lake).

The data are summarized in Tables 3, 4 and 5, respectively, with data sources identified in the tables. The chemical data presented in Table 3 are from accessible (and currently inaccessible) bedrock wells around the pit perimeter. These data indicate that water quality (dissolved constituent analyses) in the bedrock aquifer is generally good. The concentrations of constituents from the perimeter groundwater wells are generally similar to concentrations found in the pit lake (Table 5).

Water quality data shown in Table 4 indicates that the chemical quality of highwall springs is typically good. The west highwall spring in the Yerington Pit occasionally exhibits relatively high nitrate concentrations. Some possible explanations for this source of nitrate in this spring may be agricultural or lawn maintenance practices, or faulty sewage systems, at Weed Heights.

As shown in Table 5, pit lake water is neutral to slightly alkaline. The pH values for pit water suggest that acid-forming processes have not significantly influenced water quality as the pit has refilled to its current elevation. The pit water contains a limited number of constituents (e.g., copper and selenium) that have exceeded water quality criteria over the period of data collection. Appendix A provides time-concentration plots for sulfate and total dissolved solids (TDS) that are good indicators of seasonal variations in pit water quality due to dilution or evapo-concentration. Appendix A also provides time-concentration plots for selenium and copper.

Limnologic Data

Limnologic processes that will most influence water quality in the Yerington Pit Lake are hydrodynamic mixing and biological productivity (Atkins et. al., 1997). Hydrodynamic mixing is influenced by wind speed and direction relative to the geometry of the pit water surface and water density, which is a function of thermal and chemical gradients in the pit water column. Light intensity, nutrient availability and the type of plankton present in the water column will affect the biological productivity of the pit lake. Hydrodynamic and biological processes together affect the distribution of oxygen in the water column that, in turn, will influence the chemical character of the pit lake. Atkins et. al. (1997) summarized the Yerington (Anaconda) Pit Lake as:

- Seasonally stratified with respect to temperature (i.e., exhibits a thermocline in the summer and late fall that separates an upper epilimnion from the hypolimnion, at depth);
- Well-oxygenated;
- Oligotrophic (i.e., low biological productivity);
- Having a relatively large depth-to surface area ratio; and
- Holomictic (i.e., it is completely mixed during one or more winter turnover events).

Jewell (2002) reported that the Yerington Pit Lake shows limnologic behavior very similar to that of natural lakes at mid-latitude locations, with a seasonal thermocline that develops in the spring and a maximum surface temperature (approximately 25^{o}C) reached in the late summer and fall. Hypolimnitic water, below a depth of approximately 40 meters, was observed to have a relatively uniform temperature of 6.2^{o} to 6.5^{o}C. In January 1999, Jewell (2002) observed that the pit lake had a uniform temperature of approximately 6^{o}C, indicating that turnover probably occurred sometime in late 1998. Jewell (2002) suggested that the lake is monomictic (i.e., it mixes once during the coldest portion of the year) but also indicated that this mixing may occur several times over the winter months, which is consistent with the description by Atkins et. al. (1997) that the Yerington Pit Lake is holomictic (Paul Jewell, 2002; pers. comm.).

Jewell (2002) concluded that the Yerington Pit Lake "will not permanently stratify in any plausible future climate scenario and will remain oxygenated over the next several decades. Long-term stratification is precluded by relatively low concentrations of dissolved solids in ground water and the small amount of surface water entering the lake. This scenario could conceivably change if large amounts of water from the Walker River were to enter the lake in the very latest stages of filling".

These limnologic studies are provided in Appendix B of this Work Plan. Results of these studies indicate that the physical and chemical characteristics of the Yerington Pit Lake are not likely to significantly change as it refills. Given the limnologic stability of the pit lake, the observed seasonal and long-term trends of pit water quality should continue into the foreseeable future.

1.4 Data Quality Objectives

In order to ensure that data of sufficient quality and quantity are collected to meet the project objectives, the four-step Data Quality Objective (DQO) process listed below was utilized to develop the activities described in this Work Plan:

- Step 1. State the Problem;
- Step 2. Identify the Decision;
- Step 3. Identify the Inputs to the Decision; and
- Step 4. Define the Boundaries of the Study.

The problem statement (Step 1) is as follows: "Future hydrochemical conditions of the Yerington Pit Lake are not completely known, and available information must be evaluated with respect to the fate and transport of potential COCs in the pit lake that may pose a human health or ecological risk. This problem statement anticipates the conceptual hydrochemical and limnolologic model components presented in Section 2.0 that are based on the information discussed in Section 1.3. This problem statement is also based on the specific objectives described in the introduction to this Work Plan:

- Evaluate the hydraulic relationship (i.e., water levels and gradient) between the bedrock groundwater flow system that surrounds the Yerington Pit and the water in the pit;
- Develop a pit lake water balance and estimate "steady-state" hydrologic conditions to determine the long term flow direction between the bedrock flow system and the pit;
- Confirm the hydrochemical stability of the pit lake to provide the basis to assess potential impacts to groundwater, if the pit has the potential to become a flow-through system, and potential human health or ecological risk.

Step 2 of the DQO process (Identify the Decision) asks the key question(s) that this Work Plan is attempting to address: "What monitoring, sampling and analytical activities for locations in and around the Yerington Pit Lake serve to evaluate the potential risk to the environment and/or to human health, and support the development and evaluation of closure activities at the Yerington Mine Site. The criteria necessary to determine if the proposed Work Plan activities will answer this question include, but may not be limited to:

- Adequacy of collected data to evaluate the hydrologic conditions associated with the pit lake including the long-term ("steady-state") water balance and potential for the lake to become a flow-through system;
- Adequacy of collected data to document the fate and transport of potential COCs that may flow from the pit lake to the down-gradient bedrock flow system;
- Adequacy of collected data to document the hydrochemical evolution and fate of potential COCs in the pit lake under "steady-state" conditions; and
- Adequacy of collected data to assess ecological and human health risk associated with the pit lake.

Step 3 of the DQO process (Identify the Inputs to the Decision) identifies the kind of information that is needed to address the question posed under Step 2. This information would include:

- Existing geologic, limnologic and meteorologic data;
- Identification of structural elements that may focus groundwater inflows into, and possibly out from, the pit;
- Historical pit water elevation and water quality data from the pit lake;

- Historical groundwater elevation and water quality data from existing pumping wells and existing monitor wells completed in the bedrock aquifer around the pit; and
- Additional groundwater elevation and water quality data from new wells completed in the bedrock aquifer around the pit, and water quality data from the pit lake.

Step 4 of the DQO process (Define the Boundaries of the Study) defines the spatial and temporal aspects of the field monitoring, sampling and analytical activities proposed in this Work Plan. The study area is the Yerington Pit Lake, shown in Figure 3, and the adjacent surrounding area where groundwater monitoring is proposed. The time frame for conducting the investigations described in this Work Plan is as follows: installation of proposed monitoring components, including new monitor wells, will be completed by the third quarter of 2003 followed by one year of groundwater and pit water monitoring pursuant to Section 3. Additional monitoring of the Yerington Pit lake may be considered within the Final Permanent Closure Plan for the mine site.

SECTION 2.0
CONCEPTUAL HYDROGEOCHEMICAL MODEL

2.1 Purpose of Conceptual Hydrogeologic Model Development

The conceptual hydrogeochemical model for the Yerington Pit Lake is based on the data presented in Section 1.3 and general information from similar pit lakes in Nevada, summarized in a series of articles presented in the journal *Southwest Hydrology*. The conceptual model identifies the physical and chemical attributes of the Yerington Pit Lake that are relevant to the DQOs listed in Section 1.4. Of primary importance are the long-term pit lake water balance and the long-term geochemical evolution of the lake. The limnologic character of the Yerington Pit Lake is well documented, as described above. Objectives for developing and testing the pit lake conceptual model include:

- Development of pit lake water budget concepts for appropriate data collection and the prediction of long-term "steady-state" hydrologic conditions; and
- Establishment of a framework to assess the potential for ecological or human health risk from the pit water.

The Nevada Division of Environmental Protection (NDEP) approved the final version of the Conceptual Site Model for the Yerington Mine Site (CSM; Brown and Caldwell, 2002b) on November 5, 2002. The CSM flow diagram is reproduced in this Work Plan as Figure 9. The relationships between potential sources, media pathways and receptors relative to the Yerington Pit Lake shown in Figure 9 will be improved as the result of investigations proposed in this Work Plan. Figure 10 shows a schematic conceptual model of the Yerington Pit Lake, for reference in the context of the following discussion of hydrogeologic and geochemical conditions.

2.2 Hydrogeologic Conditions and Pit Lake Water Balance

As described in the *Draft Groundwater Conditions Work Plan* (Brown and Caldwell, 2002b), groundwater flow conditions in the bedrock of the Singatse Range and Singatse Spur are poorly known. However, if the hydrogeologic character of the bedrock associated with the Yerington ore deposit is similar to most or all hardrock mine sites in Nevada, groundwater flow in these intrusive and volcanic rocks will likely be influenced by fractures, faults and lithologic (i.e., intrusive) contacts. Dewatering/production wells used to depress bedrock groundwater levels around the Yerington Pit likely tapped major water-bearing structural zones. It is also likely that post-mining groundwater inflows into the pit occur from these same fracture zones. As depicted in Figure 7, the Sericite Fault appears to be one of the major structural elements in the pit, with other elements that generally trend east-west and northeast. The mapped structural elements shown in Figure 7 are hypothesized to be some of the principal groundwater flow paths in the pit.

Recharge to the bedrock groundwater flow system that enters the pit lake occurs from the Singatse Range, and the direction of flow should generally be from west to east. It is conceptualized that recharge to the pit from the bedrock results from the percolation of precipitation and run-off through overlying unconsolidated units (e.g., alluvium and colluvium) into the fractured bedrock. No indication of upwelling groundwater conditions, often represented by thermal groundwater (i.e., warm or hot springs), suggests recharge from depth into the bedrock flow system at the site.

The highwall of the Yerington Pit, as depicted in Figure 7, shows a variable thickness of unconsolidated alluvial sediments, from less than a few tens of feet on the east side of the pit to over 100 feet on the west side of the pit. Given alluvial groundwater that flows into the pit appears to be focused at the contact with the underlying igneous bedrock (Seegmiller, 1979), it is unlikely that hydraulic communication between the alluvial and bedrock aquifers is significant (i.e., seepage into the bedrock from overlying alluvium is likely to be minimal). Groundwater in the alluvium up-gradient of the pit is recharged from direct percolation of precipitation through alluvial fan materials at higher elevations, percolation of run-off from snowmelt and rainfall events, and seepage from the Walker River. Up-gradient alluvial groundwater flow that is captured by the excavated open pit results in the occurrence of highwall springs.

Ron Hershey of the Desert Research Institute (pers. comm., 2002) measured flows from a major spring and estimated flows from subsidiary seeps along the west highwall in June and December of 2000. The large spring was measured at 50 gpm in June and 44 gpm in December, and the subsidiary seeps were visually estimated at about 10 gpm during the summer and winter monitoring periods. Ron Hershey (pers. comm., 2002) also measured flows from the major spring along the east side of the pit in June and December of 2000: 130 gpm in June and 81 gpm in December. The average of these two values is about 105 gpm (170 acre-feet per year). Joe Sawyer of SRK Consulting (pers. comm., 2002) also measured seepage rates up to 120 gpm at this location.

The final recharge component to the pit lake is from direct precipitation. This value is estimated at about 5.3 inches per year. Natural discharge components may include evaporation from the pit lake surface, very minor evapo-transpiration and potential outflows to groundwater if the lake becomes a flow-through system. At the present time, the conceptual model of the Yerington Pit Lake only includes evaporation as a discharge component. Conceptually, the refilling pit lake will reach an "equilibrated" water balance condition when the pit lake surface fluctuates around some "steady-state" elevation as a result of climatic trends and seasonal effects, ultimately controlled by the recharge and discharge components described above, and shown in Figure 10.

Given the low annual rainfall at the site, about 5.3 inches or 13.5 cm per year, and the relatively high evaporation rate of about 1.2-1.5 m/yr for this area of Nevada (Jewell, 2002), the Yerington Pit Lake is located in a strongly net evaporation area (approximately 50 to 100 times greater evaporation that precipitation). Although somewhat lower evaporation rates from the surface of the pit lake may be expected due to the lower wind energy within the pit, the environment of the Yerington Pit Lake is highly evaporative. It is reasonable to assume that, like most other pit lakes developed in a strongly net evaporation setting, the Yerington Pit Lake will function as a groundwater sink characterized by a perpetual "cone-of-depression" in the bedrock aquifer (i.e., a terminal system).

A hydrologic budget, or water balance, for the Yerington Pit Lake may be described in terms of volumes (i.e., fluxes x time) by the following equation, modified from Atkinson (2002):

$$V_{in} = V_{out} + V_e + V_{\Delta s}$$

where

V_{in} = volume of groundwater, surface water and direct precipitation inflows

V_{out} = volume of groundwater outflows

V_e = volume of evaporation from pit lake surface

$V_{\triangle s}$ = changes in volume of storage (a function of the pit's stage-volume relationship)

Surface water inflows and average annual precipitation values for the Yerington Pit Lake are well known, and the volume of run-off from direct precipitation on the pit walls and surrounding capture area can be reasonably calculated. The evaporation rate is also generally known, but more detailed, site-specific data would help refine the pit water balance. The change in storage volume is well known since relatively frequent measurements of the pit lake surface elevation began in 1990. Earlier stage-volume relationships can be inferred from the asymptotic shape of the pit lake recovery curve (Figure 4B).

The rate of groundwater inflow, not well known at the present time, is proportional to two factors: 1) the hydraulic conductivity of the rocks comprising the pit; and 2) the hydraulic gradient between the water level in the pit at any point in time and some distant point where the water level has been essentially unaffected by dewatering (Atkinson, 2002). The hydraulic gradient is a function of the hydraulic conductivity and storage properties of the bedrock aquifer and the time from the start of pit dewatering. Near-pit hydraulic gradients change over time, with the steepest gradient occurring at the end of dewatering when pit lake refilling begins. Figure 8 presents a preliminary estimate of a "snapshot" in time (June to October 2002) of the estimated hydraulic gradient into the pit. The rate of infilling is also a function of the volume per unit depth of the pit, which increases significantly as the pit lake refills (Atkinson, 2002), and the saturated thickness of the adjacent bedrock aquifer.

The proposed field investigations described in Section 3.0 will provide the data necessary to develop a defensible water balance for the Yerington Pit Lake. The water budget will allow for the prediction of when the "equilibrated" pit lake elevation will occur, assuming physical conditions that control recharge and discharge components remain the same. The hydrologic budget for the pit lake will, in turn, control the chemical evolution of the pit lake water.

2.3 Geochemical Evolution of the Pit Lake

As described in the *Draft Groundwater Conditions Work Plan* (Brown and Caldwell, 2002b), the Yerington Pit Lake does not currently, nor in the future will, directly affect groundwater quality in the shallow alluvial aquifer. An indirect effect on alluvial groundwater quality is a result of the excavation of the Yerington Pit. The pit has reduced recharge of presumably "good-quality" groundwater to the alluvial flow system due to the flows of highwall springs and seepage of Walker River surface water into the pit.

If water flows through the pit into the down-gradient bedrock flow system under hydraulic "steady-state" conditions in the future, these outflows may affect bedrock groundwater quality (Figure 10). "Steady-state" hydraulic conditions as defined in this Work Plan represent a nominal five-year period of time during which pit lake surface elevations and surrounding groundwater elevations have stabilized (i.e., no longer continuing to increase), recognizing that seasonal variations or variations due to climate conditions may occur. It is assumed that "steady state" hydraulic conditions will control "steady-state" water quality characteristics of the pit lake, recognizing that seasonal geochemical variations will occur, as described below.

The geochemical data presented in Table 3 indicate that the chemical quality of bedrock groundwater samples (dissolved analyses) associated with the pit lake show temporal variability, but have not significantly changed from 1993 to the present. Individual wells presented in Table 3 would be expected to show similar geochemical characteristics (i.e., concentrations of dissolved constituents) over time. Conceptually, each sampled groundwater well may yield somewhat different groundwater quality as a result of travel time, and the lithologic and mineralogic character of the rock mass through which the sampled groundwater traveled.

Concentrations of constituents from pit lake samples reflect seasonal and longer-term trends, as seen in time-concentration plots of selected constituents from the surface of the pit lake, and at depth (Appendix A). Graphs for selenium and copper show decreasing values over time for these constituents. Pit surface sample concentrations for these constituents indicate seasonal fluctuations as a result of spring dilution and late summer evapo-concentration. Time-concentration plots for total dissolved solids (TDS) and sulfate (a primary component of TDS) also indicate seasonal evapo-concentration and dilution effects in the pit lake, particularly in surface samples (in addition to sulfate, TDS components may include salts). Additional chemical and limnological processes (e.g., adsorption and precipitation) may also affect pit water quality. The observed temporal concentration decreases and seasonal fluctuations provide important empirical data upon which the chemical evolution of the pit lake may be conceptualized.

Given the observed pit water quality data and the limnologic character of the pit lake (e.g., annual mixing and relatively low biological productivity), the chemical evolution of the pit water is hypothesized to remain similar to what has been monitored to date. In other words, constituent concentrations are likely to continue to decrease as the pit continues to refill. The quality of pit lake water, at the surface and at depth, is only temporally affected by evaporative concentration as described by the transient relationship presented below (from Atkinson, 2002):

$$C_t = \frac{M_t}{V_t} = \frac{M_{t-1} + \sum(V_{in} C_{in} - V_{out} C_{t-1})}{V_{t-1} + V_{\Delta s}}$$

where

C = concentration
M = mass in solution
V = volume of water in pit lake
t = time

Conceptually, under hydrochemical "steady-state" conditions, if constituent concentrations increase in the epilimnion as a result of evapo-concentration, solids (e.g., salts, hydroxides, sulfates) will precipitate. This process results in the sequestering of metals and other constituents from the pit water column, as precipitates settle and accumulate on submerged pit walls and benches. This conceptual model of pit lake chemical evolution is based on the following assumptions: 1) groundwater-wall rock interactions will become less important over time given the submerged condition of the previously exposed wall rock; 2) the quality of bedrock groundwater remains the same; and 3) seasonal mixing across thermal and chemical strata that develop within the pit lake will continue to occur.

Pit lakes can have up to three horizontal strata or zones: 1) a deep chemically dense isolated layer at depth that does not become involved with annual mixing (not observed at the Yerington Pit Lake); 2) an epilimnion, or surface layer above a thermocline; and 3) a hypolimnion, or colder layer below a thermocline. Portions of the water column that become involved in seasonal turnover and mixing occur within a "mixolimnion". The transition from epilimnion to hypolimnion is defined by rapid decreases in oxygen content (e.g., to less than 1 mg/l), a rapid increase in salinity and a rapid decrease in temperature. Oxygen depletion is a strong indicator of biological productivity, and anoxic conditions can reduce and dissolve metal-bearing hydrous ferric oxides. Jewell (2002) did not anticipate potential increases in dissolved metals concentrations with depth in the Yerington Pit Lake, due to anoxic conditions, and also predicted that stratification in the long-term would not occur due to the relatively low concentrations of dissolved solids in groundwater and low inflows of surface water.

The hydrogeochemical conceptual model described above links the pit water balance to evaporative concentration as the dominant process that influences pit water quality. Pit lakes are referred to as "terminal" when evaporation is sufficiently dominant to create a perpetual groundwater sink (i.e., there is no potential to impact down-gradient water quality). A "flow-through" pit lake is one that experiences short or long-term conditions where evaporation is less dominant than recharge, where pit water has the potential to flow from the pit into the down-gradient aquifer.

Whether the Yerington Pit will be a terminal or flow-through system will depend on its water balance components including lake size and geometry, hydraulic conductivity of the adjacent fractured bedrock and climatic conditions. The water balance analysis proposed in this Work Plan will provide the basis to evaluate this question. However, the available climatic, limnologic and chemical data suggest that the Yerington Pit will be a terminal system with water quality characteristics similar to, or better, than observed at present.

SECTION 3.0
WORK PLAN

3.1 Proposed Field Investigations

This Work Plan describes site investigation activities that will satisfy the DQOs presented in Section 1.4. Proposed data collection activities will improve upon the current understanding of hydrologic and chemical conditions associated with the Yerington Pit Lake and support the evaluation of human health and ecological risk associated with potential COCs in the pit water. The proposed investigations will focus on providing data to:

- Quantify pit lake water balance components, and estimate the time frame for the pit lake to reach hydrochemical "steady-state" conditions;
- Establish the hydraulic relationship between groundwater and pit lake surface elevations to further evaluate the concept that the pit lake will a terminal system ; and
- Determine if the water quality in the pit lake poses a risk to groundwater, or to human health or ecological receptors.

The results of field investigations and one year of subsequent monitoring activities presented in this Work Plan will be presented in a Data Summary Report. As proposed in the Closure Scope of Work, an assessment of human health and ecological risk associated with the pit lake will be presented in the Final Permanent Closure Plan for the Yerington Mine Site.

Water Balance Components

Atlantic Richfield is currently collecting site-specific climatologic data from the weather station installed at the northern margin of the mine site. Data pertinent to the pit lake water budget currently being collected include temperature, rainfall and snowfall amounts, and wind speed. In addition to the data collected by the meteorological station, Atlantic Richfield proposes to collect evaporation data from the approximate elevation of the pit lake for one year. The location of the proposed pan evaporation monitoring location is shown in Figure 11.

Evaporation monitoring will be conducted on an appropriate basis for the proposed one-year period of pit lake monitoring activities using a Class A U.S. National Weather Service

This is a draft report and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; please consult the final report.

evaporation pan. The stainless steel pan measures 47.5” in diameter by 10” deep. The pan will be installed on a wooden platform (e.g., pallet) in a location free from obstructions and interferences, no closer than four times the height of the pan. Measurements at approximately the same time will be obtained manually, using a hook gauge and Stillwell, or automatically with a water level sensor attached to a datalogger. The pan will be refilled with pit water approximately every four days during periods of high evaporative losses and weekly during low loss periods. The level of the water in the pan will be maintained between two and three inches below the top of the pan to ensure the most accurate measurements. Besides maintaining pan water levels, basic maintenance will include keeping the pan free of algae, rust, damage and wildlife interference.

An additional water balance component includes the pit lake surface elevation, where measurements will allow for the calculation of changing volume and storage of water in the pit over time, given the stage volume relationship provided in Table 1. These measurements will initially be made at the location shown on Figure 11. However, as the pit lake rises, the pit lake monitoring site will progressively move up the access ramp. Pit lake level measurements will be collected monthly.

Related data collection activities that will be used to evaluate the “capture area” (i.e., “cone-of-depression”) around the evolving and “steady-state” pit lake include the installation of groundwater monitor wells and the measurement of bedrock groundwater elevations over time. Atlantic Richfield proposes to collect these groundwater elevation measurements at the existing and proposed locations shown on Figure 11. Precise locations of the new monitor wells will be established after an on-site review of structural features exposed on the pit highwalls. Coordinates of the existing and new monitor wells will be surveyed in conjunction with the pit surface monitoring location and the surface water flow measurement locations. Groundwater elevation measurements are proposed to be collected on a semi-annual basis (early Spring and late Summer) to establish a baseline for seasonal fluctuations.

Surface water flow rates from highwall springs and seeps will be measured to confirm the quantity of recharge from these surface water flows. Flow rates from the springs will be measured on a monthly basis using a flume or weir at the locations shown on Figure 11. Precise monitoring locations for spring/seep monitoring will be determined in the field, in the context of site health and safety issues, and subsequently field-staked and surveyed. Spring/seep flow measurements will only be measured if it is safe to do so, otherwise flows will be estimated.

After one year of data collection, Atlantic Richfield will use existing data (described in Section 1.3) and newly collected data to evaluate the pit lake water budget and estimate the time required for the pit lake to reach "steady-state" hydraulic conditions. Future pit lake hydraulic conditions will be predicted using an analytical model developed for pit refilling calculations developed to support closure investigations at similar open pit mines in Nevada and California. The predicted rise in pit lake elevations will be calibrated with the information presented in Section 1.3 and the proposed empirical data sets described in this Work Plan. The purpose of the pit-refilling model is to refine the anticipated time frame that will be required for the pit lake to reach "steady-state" hydraulic conditions, which will be useful in the evaluation of closure options for this mine unit.

<u>Pit Lake and Groundwater Quality</u>

Atlantic Richfield proposes to conduct water quality sampling from the surface of the pit water and from existing and proposed bedrock groundwater monitor wells, shown in Figure 11, during the early Spring and late Summer (e.g., March and September). One or more existing wells may substitute for a proposed well pending initial field investigations to determine the accessibility and suitability of the existing well for groundwater elevation measurements and water quality sampling.

The proposed monitoring schedule for pit water quality would establish a baseline for seasonal fluctuations in pit lake water quality that should correspond to periods of stratification and mixing, based on the limnologic data presented in Section 1.3. This schedule provides for monitoring of potential dilution effects in the pit lake anticipated to result from winter and spring recharge events, and monitoring of evapo-concentration effects anticipated to result from higher summer temperatures. Based on the limnologic and water quality data presented in Section 1.3 (given the similar water quality data from historic samples collected at the surface and at depth; Table 5 and Appendix A), no water quality sampling at depth is proposed.

Water quality sampling and analyses will be performed in accordance with Section 3.2 of this Work Plan and the QAPP. A Nevada-certified laboratory will perform the analyses for the constituents shown in Table 6 for dissolved and total concentrations for pit water and groundwater, respectively. All laboratory results will be presented in the Data Summary Report for the Yerington Pit Lake.

3.2 Quality Assurance/Quality Control Procedures

Proposed site investigation activities will follow the quality assurance/quality control (QA/QC) procedures presented in the Draft Quality Assurance Project Plan (QAPP), and those described in this section to ensure that the type, quantity and quality of data collected are reliable and provide the information needed to satisfy the DQOs listed in Section 1.4. QA/QC issues include:

- Monitor well drilling and construction;
- Surveying of monitoring locations;
- Collection of field data and sampling protocols, including handling and shipment;
- Selection of appropriate analytical laboratory detection limits; and
- Identification of confidence levels for the collected data.

Monitor Well Drilling and Construction

All monitor well boreholes will be drilled using a drilling technique that allows for lithologic logging of borehole samples to assist in the evaluation of site hydrostratigraphy. All wells will be constructed to allow for the collection of groundwater elevation measurements and water quality samples, in accordance with the QAPP. The Data Summary Report for Groundwater Conditions will present all pertinent information from the well drilling and construction activities. Prior to the construction of new monitor wells to be completed in the bedrock aquifer around the perimeter of the Yerington Pit, existing bedrock wells will be evaluated for their potential use in the proposed monitoring of groundwater elevations and water quality.

The wells will be constructed of nominal two-inch diameter, Schedule 40 PVC flush-coupled well casing and 0.02-inch slotted screens. A 20-foot screened interval will be installed in the upper 40 feet of saturated bedrock with a filter pack consisting of nominal 10/20 silica sand. The well construction design is based on the recognition that groundwater elevations in the bedrock surrounding the pit will continue to rise after the construction of the proposed wells. The annulus will be backfilled with bentonite or grout to the natural ground surface. The wells will be completed with a nominal two-foot casing above the ground surface, cemented in-place, and locking caps installed at the top of the well casings.

Surveying

Measurement of latitude/longitude coordinates and top-of-casing elevations for existing and new monitor wells, and for surface water monitoring locations, will be performed with a real-time kinematic global-positioning satellite (GPS) device. This portable device allows an accuracy of at least three millimeters (0.01 feet) for latitude, longitude, and elevation. This degree of accuracy is sufficient for water level measurements to be used in the calculation of groundwater direction and hydraulic gradient. Measurements of coordinates and elevations shall be recorded in the field notebook immediately after readings are observed, and will be automatically logged in the GPS data-logger for later down-loading and cross-checking of data recorded in the field. The coordinates will be used to properly position the wells and monitoring locations on a site plan, along with a permanent record of each well top-of-casing elevation.

Groundwater Field Parameters

Field measurements will include static groundwater elevations, dissolved oxygen, pH, electrical conductivity and temperature. The field parameter measurements will be recorded to the accuracy allowed by the measurement method and equipment, with particular attention being given to proper calibration of instruments. Prior to sampling at each monitoring well, the pH, dissolved oxygen, temperature, and electrical conductivity probe(s) shall be calibrated and the conductivity probe shall be checked with a standard. Proper operation of the ground water elevation probe shall be checked prior to use by immersing the probe in water to ensure the audible signal is produced. After sampling is completed, a drift check shall be performed with each instrument, using the same standard solutions used to calibrate. The purpose of the drift check is to assess the loss of accuracy that often occurs when measurements are performed at different locations. Instrument calibration information and instrument accuracy limits will be recorded in the field notebook and presented in the Data Summary Report. The methods and minimum detection limits of the pH, dissolved oxygen, temperature, and electrical conductivity devices are shown below:

Groundwater Field Parameters		
Parameter	**Method**	**Detection Limit**
Conductivity	EPA 120.1, meter	1.0 µS/cm
Dissolved Oxygen	EPA 360.1, probe	0.1 mg/l
PH	EPA 150.1, meter	0.1 standard units
Temperature	Standard Methods 212, Thermometer	0.1 ^{o}C

Field parameters will be measured in one day to limit error in calculating hydraulic gradient or flow direction due to potential diurnal fluctuations in groundwater elevation, and will be recorded in a bound field notebook. All equipment used to measure depth-to-water and other physical parameters in each well will be decontaminated between wells by washing in an Alconox detergent solution with subsequent clean-water rinse. Measurement of field parameters in monitoring wells shall occur in order of least contaminated to greatest contaminated, as determined by the previous quarter's laboratory analytical results.

Groundwater Sampling

New and existing monitor wells will be purged using either a submersible pump or clean, disposable Teflon bailer, depending on depth-to-water, total depth of the well, and well diameter. The equipment and purging method used for monitor wells will be noted on each field data sheet. During purging, pH and electric conductivity will be monitored with a calibrated, portable field instrument in order to determine stabilization of these parameters between each purged well casing volume. A minimum of three casing volumes is purged from each well until pH and electric conductivity readings stabilize to within 10 percent of the previous casing volume. If a well is purged dry, no sample will be collected until it has recharged to within 80 percent of its original depth-to-water, or no more than 24 hours. Existing large diameter wells will be purged until field parameters stabilize, and a sample will be collected prior to purging three well casing volumes.

After field parameters have stabilized, a groundwater sample will be collected using a disposable Teflon bailer or discharge from the submersible pump. The sample will be decanted into an appropriate sample container depending on the required analysis. Both filtered samples for dissolved metals and, for selected monitor wells and domestic wells, unfiltered samples for total metals will be each collected in 500-milliliter (mL) bottles. Non-metals samples shall be collected in 1,000-mL bottles, unfiltered, with no acid preservation. Sample bottles for the blank shall not be triple-rinsed prior to being filled, so that any contamination from bottles alone would be detected. Immediately following collection, samples shall be placed into an insulated cooler chilled with ice to an approximate temperature of four degrees centigrade. The samples will then be transported to the analytical laboratory via overnight mail or personal delivery. Sample containers, preservation methods, and filtering methods are summarized below.

Decontamination of purging equipment will be performed between each sampling event by submerging and scrubbing the outside of the pump and associated hosing in an Alconox detergent bath, then twice rinsing the outside of the pump in deionized water. At least five gallons of Alconox detergent solution and then five gallons of deionized water are run through the internal portion of the pump to reduce the potential of cross contamination between wells.

All purged groundwater and decontamination solution will be collected in DOT-approved 55-gallon drums and properly disposed of or recycled. For each groundwater sampling event, pertinent information will be recorded.

Spring Seep Flow Measurements

Spring/seep flows will be measured with a cutthroat flume or weir. The flume will be temporarily placed in the spring discharge conveyance, leveled and allowed to equalize flow between the inlet and outlet prior to recording the stage in the flume. A typical flume has a staff gage installed on the flume that is scaled in 0.01-foot increments. The recorded stage is converted to flow rates using a rating table. An eight-inch flume will be used for flow measurements in the range from 0.2 gpm to 1,000 gpm when site conditions permit.

Pit Water Sampling and Field Parameters

Pit water samples will be collected as discrete samples from the edge of the ramp leading down to the pit lake. Atlantic Richfield anticipates that the sample location will progressively move up the ramp as the pit lake refills. Equipment and instruments used for surface water sampling and field monitoring may include, but are not limited to:

- Temperature/pH/conductivity (probe/meter)
- Dissolved oxygen (probe/meter)
- Flow rate (flumes or probe/meter)
- Sampling devices (e.g. pumps or disposable bailers)
- Tape measure
- Waders or hip boots

Manufacturer-supplied calibration information for each instrument will be used as guidance in calibrating field devices. Each field instrument will be calibrated prior to use and a drift check performed after sampling is completed. The drift check will be performed using the same standard solutions or test used to calibrate. The purpose of the drift check is to assess the loss of accuracy that often occurs when measurements are performed at different sample locations under different surface water conditions and target constituent concentrations. Instrument calibration information and instrument accuracy limits will be recorded in the field notebook and presented in the Data Summary Report.

Prior to sampling, the pH, dissolved oxygen, temperature, and/or electrical conductivity probe(s) will be calibrated and the conductivity probe, if used, will be checked with a standard (Section 2.4.1). The methods and minimum detection limits of the pH, dissolved oxygen, temperature, and electrical conductivity devices are shown below:

Pit Water Field Parameters		
Parameter	**Method**	**Detection Limit**
Conductivity	EPA 120.1, meter	1.0 µS/cm
Dissolved Oxygen	EPA 360.1, probe	0.1 mg/l
PH	EPA 150.1, meter	0.1 standard units
Temperature	Standard Methods 212, Thermometer	0.1 ^{o}C

Field parameters will be measured in one day to limit error in calculating flow rates due to potential diurnal fluctuations in river or stream elevation, or in diurnal fluctuations of temperature and dissolved oxygen. All measurements will be recorded in a bound field notebook. The physical measurements will be recorded to the accuracy allowed by the measurement method and equipment, with particular attention being given to proper calibration of instruments. Instrument accuracy limits will be specified in the results section of the Data Summary Report.

Measurements of surface water conductivity, dissolved oxygen, pH, and temperature will be collected from two to three inches below the pit water surface. Temperature and conductivity surface water measurements will be collected by placing the test cup and probe below the water surface. Measurements of surface water pH, dissolved oxygen and electrical conductivity will be collected by placing the probe below the water surface, allowing the pH value to stabilize, and recording the value. In rivers, streams, or ponds, care will be taken to prevent disturbance of sediment or soil along the bank that could roll down into the water.

Sample Identification and Preservation

Sample labels shall be completed and attached to each laboratory sample container prior to the collection of water quality samples. Strict attention will be given to ensure that each sample label corresponds to the collection sequence number marked on the bottle prior to sample collection. The labels shall be filled out with a permanent marker and shall include the following information:

- Sample identification (well location)
- Sample date
- Sample time
- Sample preparation and preservative
- Analyses to be performed
- Sample type
- Person who collected sample

Each sample will be tracked according to a unique sample field identification number assigned when the sample will be collected. This field identification number consists of three parts:

- Sampling event sequence number
- Sampling location
- Collection sequence number

For example, a sample collected during the second sampling event at a hypothetical monitor well MW-4 will be labeled: 002MW004. Blanks and duplicate samples for quality assurance will be labeled in the same fashion, with no obvious indication of their sample location or quality. For example, the duplicate sample to the one stated above might be labeled: 002MWD111, with a field notebook entry that this identification number corresponds to 002MW004.

Procedures for maximum holding times, storage conditions, and preservative method are presented below:

Sample Control Procedures

Parameter	Amount for Analysis	Container	Filtering	Maximum Hold Time	Storage Conditions	Preservatives
TDS, TS	1,000 mL	1,000 mL HDPE	None	7 days	4°C	none
Sulfate, Chloride, Bromide, Flouride	500 mL	1,000 mL HDPE	None	28 days	4°C	none
Nitrate	100 mL	500 mL HDPE	None	48 hours	4°C	H_2SO_4 to pH<2
Total Metal	Varies per metal	1,000 mL HDPE	None	6 months*	4°C	HNO_3 to pH<2
Dissolved Metal	Varies per metal	1,000 mL HDPE	0.45 µm	6 months*	4°C	HNO_3 to pH<2
Total Recoverable Metal	Varies per metal	1,000 mL HDPE	None	6 months*	4°C	HNO_3 to pH<2
Acidity/ Alkalinity	100/200 mL	500 mL HDPE	None	14 days	4°C	none

TDS= Total Dissolved Solids
TS= Total Solids
HNO_3= Nitric acid

* Mercury= 28 days; Chromium VI= 24 days
HDPE= High-density polyethylene

The following sample preservation methods will be followed for collected groundwater samples:

- If the sample is to be analyzed for dissolved metals, filter sample through a 0.45-micron filter using an inline filter immediately after sample collection.
- If the sample is to be analyzed for total metals, do not filter. For either dissolved or total metals, add nitric acid to the collected sample until the pH is less than 2.
- Check the pH by pouring a small amount of sample into the bottle cap and checking the pH with pH paper.
- Discard the liquid in the cap after checking the pH.
- Replace the cap, place the sample container in a sealed zip-loc plastic bag, and cool the sample to 4°C by immediately placing it in an insulated chest with containerized ice.
- Indicate on the sample label what the requested analysis is (e.g., dissolved or total).
- Observe the maximum holding times and storage conditions for all collected water samples.

Sample Handling and Transport

The QA objectives for the sample-handling portion of the field activities are to verify that decontamination, packaging and shipping are not introducing variables into the sampling chain which could render the validity of the samples questionable. In order to fulfill these QA objectives, blank and duplicate QC samples will be used as described below. If the analysis of any QC samples indicates that variables are being introduced into the sampling chain, then the samples shipped with the questionable QC sample will be evaluated for the possibility of contamination.

Duplicate samples will be collected at a frequency of one in eight-to-ten samples for each analysis. Duplicate samples will be collected by filling the bottles for each analysis at the same time the original sample is collected. Each sample from a duplicate set will have a unique sample number labeled in accordance with the identification protocol, and the duplicates will be sent "blind" to the lab. For quality assurance purpose, no special labeling indication of the duplicate shall be provided.

A field sample will be designated as the "lab QC sample" at a frequency of 1 per 20 samples (including blanks and duplicates) for all parameters. The lab QC sample is the sample the laboratory will use for its internal quality control analyses. The lab QC sample for water analyses will be a double volume sample. The lab QC sample will be a sample that is representative of other contaminated samples. The sample containers and paperwork will be clearly labeled "Lab QC Sample".

A blank sample will be collected by pouring the blank water directly into the sample bottles at one of the sample locations. De-ionized water will be used for collecting blank water samples. For quality assurance purpose, field blanks will be labeled in the same manner as other samples and will be sent "blind" to the lab, with no special indication of the nature of the sample.

Chain-of-custody protocol will be followed throughout the transport process. Each chain-of-custody shall contain the following information:

- Project name
- Sampler's name and signature
- Sample identification
- Date and time of sample collection
- Sample matrix
- Number and volume of sample containers
- Analyses requested
- Filtration completed or required
- Method of shipment

The following sample packaging and shipment procedures will be followed for collected water samples to ensure that samples are intact when they arrive at the designated laboratory:

1. Place a custody seal over each container, and place each container in a zip-loc plastic bag and seal the plastic bag shut.
2. Place the sealed containers in the insulated ice chest.
3. If required, fill empty spaces in the ice chest with either ice, pelaspan (styrofoam popcorn), or bubble-pack wrap to minimize movement of the samples during shipment. Contained ice shall be double bagged in zip-loc plastic bags to avoid water leakage.

4. Enclose the chain of custody form and other sample paperwork in a zip-loc plastic bag. If shipping the ice chest, tape the plastic bag to the inside of the ice chest lid. If self-transporting the ice chest, tape the plastic bag to the outside of the ice chest lid. Keep a copy of all paperwork.
5. Seal the ice chest shut with strapping tape and place two custody seals on the front of the cooler so that the custody seals extend from the lid to the main body of the ice chest. Place clear tape over each custody seal on the outside of the ice chest.
6. If shipping the ice chest, label it with “Fragile” and “This End Up” labels. Include a label on each cooler with the laboratory address and the return address.
7. Transport ice chests to the appropriate laboratory within 24 hours by hand-delivery or via express overnight delivery.

Laboratory Analyses and QA/QC

Laboratory analyses for groundwater samples collected as part of this Work Plan will be conducted in accordance with Table 5. Groundwater samples will be analyzed for dissolved metals, sulfate, nitrate, chloride, acidity, alkalinity, hardness and total dissolved solids. Pit water samples will be analyzed for total and dissolved metals, sulfate, nitrate, chloride, acidity, alkalinity, hardness and total dissolved solids. A Nevada-certified laboratory shall perform laboratory analyses. Criteria that are qualitative and quantitative indictors of laboratory data quality are precision, accuracy, representiveness, completeness and comparability, as described below:

- Precision is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions (usually expressed in terms of the relative percent difference or standard deviation).
- Accuracy is the degree of agreement of a measurement with an accepted reference or true value. Usually expressed in terms of percent recovery.
- Representiveness refers to a sample or group of samples that reflects the characteristics of the media at the sampling point. It also includes how well the sampling point represents the actual parameter variations that are under study.
- Completeness describes the amount of valid data obtained from a series of measurements relative to the amount that anticipated to achieve the DQOs for this Work Plan.
- Comparability expresses the confidence with which one data set can be compared to another. Data comparability can be ensured by reporting each data type in consistent units (e.g., all field measurements will be reported in consistent units and analytical methods will be similar or equivalent for all rounds of sampling). Comparability and representiveness are also ensured by the use of established field and laboratory procedures and their consistent application.

Documentation

Summary of field measurement and sampling activities will be recorded in a field notebook with integral bound pages, and entries will contain accurate and inclusive documentation of project activities in objective and factual language. Entries will be made using permanent waterproof ink, and erasures are not permitted. Errors shall be single-lined out, should not be obscured, and initialed and dated. The person making the entries will sign at the beginning and the end of the day's entries, and a new page will be started for each day.

The following entries will be made to the bound site logbook and/or filed log sheets:

- General descriptions of weather conditions
- Location of each sampling point
- Data and time of sample collection (field log sheets.)
- The type of blank collected and the method of collection
- Field measurements made, including the date and time of measurements
- Calibration of field instruments
- Reference to photographs taken
- Date and time of equipment decontamination
- Field observations and descriptions of problems encountered
- Duplicate sample location

3.3 Site Job Safety Analysis

A site-specific Job Safety Analysis (JSA) is presented in Appendix C. This JSA has been prepared in the context of the Health and Safety Plan (SHSP) for the Yerington Mine Site. The SHSP identifies, evaluates and prescribes control measures for health and safety hazards, and describes emergency response procedures for the site. SHSP implementation and compliance will be the responsibility of Atlantic Richfield's contractor, with Atlantic Richfield taking an oversight and compliance assurance role. Any changes or updates will be the responsibility of the contractor with review by Atlantic Richfield Safety Representative Lorri Birkenbuel. Copies of the SHSP are located at the site, in Atlantic Richfield's Anaconda office, and in the contractor's office. The SHSP includes:

- Safety and health risk or hazard analysis;
- Employee training records;
- Personal protective equipment (PPE);
- Medical surveillance;
- Site control measures (including dust control);
- Decontamination procedures;
- Emergency response; and
- Spill containment program.

The SHSP includes a section for site characterization and analysis that will identify specific site hazards and aid in determining appropriate control procedures. Required information for site characterization and analysis includes:

- Description of the response activity or job tasks to be performed;
- Duration of the planned employee activity;
- Site topography and accessibility by air and roads;
- Safety and health hazards;
- Hazardous substance dispersion pathways; and
- Emergency response capabilities.

All contractors will receive applicable training, as outlined in 29CFR 1910.120(e) and as stated in the SHSP. Copies of Training Certificates for all site personnel will be attached to the SHSP. Personnel will initially review the JSA forms at a pre-entry briefing. Site-specific training will be covered at the briefing, with an initial site tour and review of site conditions and hazards. Records of pre-entry briefings will be attached to the SHSP.

The JSA for this Work Plan incorporates individual tasks, the potential hazards or concerns associated with each task, and the proper clothing, equipment, and work approach for each task. Tasks and associated potential hazards included in the JSA are outlined below:

PROJECT TASKS AND ASSOCIATED POTENTIAL HAZARDS YERINGTON MINE SITE	
SEQUENCE OF BASIC JOB STEPS	**POTENTIAL HAZARDS**
1. Monitoring Well Installation: drilling rig mobilization and setup	1. Traffic and pedestrian mishaps and resulting bodily injury. 2. Drilling into underground utilities 3. Striking overhead lines or objects with drill mast or casing material. 4. Physical hazards associated with handling and transferring fuel to machinery. These include ignition/explosion, dermal irritation, inhalation of fumes, accidental ingestion, and eye contact. 5. Hazards sue to irregular terrain near pit.
2. Monitoring Well Installation: drilling activities	1. Injury to hearing from noise. 2. Inhalation hazards from dust from drilling activities. 3. Physical injury from moving parts of machinery. 4. Physical hazards to personnel on the ground in the vicinity of the heavy machinery.
3. Monitoring Well Installation: well construction	1. Inhalation of silica sand, bentonite, or concrete dust. 2. Eye injury or irritation from splashing ground water. 3. Physical hazards associated with use of hand tools to tighten or loosen augers.
4. Flow Measurements	1. Physical hazards associated with use of hand tools and instruments. 2. Slipping or falling on wet ground surface; falling; access to measurement sites along pit highwall locations.
5. Survey Monitoring Wells	1. Traffic and pedestrian mishaps and resulting bodily injury. 2. Lightning.
6. Collect Monitoring Well Field Parameter Measurements	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
7. Purge Monitoring Wells	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
8. Prepare sample bottles and dress in appropriate PPE.	1. Burn or corrosion from acid spillage, if sample bottles do not have acid already in them.
9. Collect Ground Water Samples and Decontaminate Equipment	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface.
10. Collect Pit Water Samples and Decontaminate Equipment	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface; access to pit bottom; falling into pit lake.
11. Collect Pit Water Elevation and Evaporation Pan Measurements	1. Skin irritation from dermal or eye contact. 2. Slipping or falling on wet ground surface; access to pit bottom; falling into pit lake.
12. Package and Transport Ground Water Samples to Laboratory	1. Traffic and pedestrian mishaps and resulting bodily injury.
13. All Activities	1. Slips, Trips, and Falls
	1. Back, hand, or foot injuries during manual handling of materials.
	1. Heat exhaustion or stroke.
	1. Hypothermia or frostbite.

SECTION 4.0

REFERENCES CITED

Anaconda Mining Company, 1968, *Letter from C.J. Houck (Asst. General Manager) to Charles Brinckerhoff (Chairman of the Board) with attached Vat Leaching summary*.

Applied Hydrology Associates, 2002, *2001 Annual Monitoring and Operation Summary, Pumpback Well System, Yerington, Nevada*. Prepared for Atlantic Richfield Company.

Atkins, D., Kempton, J.H., Martin, T. and Maley, P., 1997, *Limnologic Conditions in Three Existing Nevada Pit Lakes: Observations and Modeling using CE-QUAL-W2*, Fourth International Conference on Acid Rock Drainage, Proceedings, Vol. II, p. 697-713.

Atkinson, L.C., 2002, *The Hydrology of Pit Lakes*, Southwest Hydrology, vol. 1, no. 3, p. 14-15.

Brown and Caldwell, 2002a, *Closure Scope of Work for the Yerington Mine Site.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2002b, *Conceptual Site Model for the Yerington Mine Site.* Prepared for Atlantic Richfield Company.

Brown and Caldwell, 2002c, *Draft Groundwater Conditions Work Plan*. Prepared for Atlantic Richfield Company.

Dilles, J.H. and Gans, P.B., 1995, *The chronology of Cenozoic volcanism and deformation in the Yerington area, western Basin and Range and Walker Lane*, Geological Society of America Bulletin, vol. 107, no. 4, p. 474- 486.

Hershey, R.L., 2001, *Presentation: Yerington Mine Pit Lake*, presented to the Yerington Mine Technical Advisory Committee.

Huxel, C.J., 1969, *Water Resources and Development in Mason Valley, Lyon and Mineral Counties, Nevada, 1948-65*. State of Nevada Department of Conservation and Natural Resources, Division of Water Resources, Water Resources Bulletin No. 38.

Jewell, P.W., 2002, *Stratification and Geochemical Trends in the Yerington Pit Mine Lake, Lyon County, Nevada*, Unpublished report prepared for the Nevada Division of Environmental Protection.

Moreno, J. and Sinton, P., 2002, *The Hydrology of Pit Lakes*, Southwest Hydrology, vol. 1, no. 3, p. 20-21.

Piedmont Engineering, 2001, *Yerington Shallow Aquifer Data Evaluation Report*, prepared for Atlantic Richfield Company.

Proffett, J.M., Jr., and Dilles, J.H., 1984, *Geologic Map of the Yerington District, Nevada*. Nevada Bureau of Mines and Geology, Map 77.

Proffett, J.M., Jr., 1977, *Cenozoic geology of the Yerington district, Nevada, and implications for the nature of Basin and Range faulting*, Geological Society of America Bulletin, vol. 88, p. 247- 266.

Seegmiller Associates, 1979, *Slope Stability Effects of Pit Water Storage, Yerington Mine, Lyon County, Nevada*, Prepared for the Anaconda Mining Company.

Wilson, J.R., 1963, *Geology of the Yerington Mine*, Mining Congress Journal, vol. 49, no. 6, p. 30-34.